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CALIFORNIA
FOREST and RANGE
EXPERIMENT STATION
STEPHEN N. WYCKOFF, DIRECTOR

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FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

FOREWORD

This Station's annual report for 1951 observed the 25th anniversary of our research in wild land management by summarizing the status of the research program at that time. For 1952 we are reporting some highlights of current studies in an effort to keep those interested in the program informed on what we are doing. These studies are of widely varied nature. Some are long-time projects; for example, the continuing process of measuring tree growth on permanent sample plots; or the quantitative study of soil movement in Los Angeles River watershed, which is just getting started. Other studies, though of shorter duration, are parts of continuing programs; for example, the trials of herbicides, cold storage methods, and protective screens, which are part of our search for knowledge to aid in regeneration of timber stands.

The work of the Station is reported separately for each of eight divisions. But it is worth emphasizing here that study of biological problems often requires a team-work approach rather than neatly compartmented work. Our studies of brushland improvement under auspices of the Research and Marketing Administration, for example, depend on many disciplines. Range specialists conduct many field studies and work with other specialists in fire behavior, soils, and hydrology. Again, testing of hybrid pines requires work by both silviculturists and geneticists. And fire, forest, range, and watershed specialists are all drawn into the study of methods for appraising fire damages.

We have not worked alone on the studies highlighted in this report. Besides the financial and other aid of many cooperators mentioned here, we have had valuable advice on our program from industries, foresters, ranchers, and advisory boards. We are grateful for this help and hope it will continue. Also, other agencies are working independently on similar problems. This, too, is helpful and should continue. The pressure being exerted on the region's wild land resources by a rapidly increasing population will make necessary the best efforts of many minds if the resources are to be used wisely.

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FOREST MANAGEMENT RESEARCH

In order to insure that first things are being put first the Division of Forest Management Research began a critical review of its program in 1952. The review probably will not be completed before another year, but certain things are already evident. Perhaps the most significant considerations are the rapid acceleration in the rate of timber harvesting and the increasing opportunity to employ more intensive forestry practices on both publicly and privately owned forest lands. First, the cut of saw timber in California increased from 2.3 billion board feet in 1945 to 5 billion board feet in 1951. Second, with higher stumpage prices, more efficient logging methods, and properly located access roads, growing timber as a crop looks like a better business proposition than ever before.

The review has shown that the California region still possesses a vast store of mature and overmature timber--around 200 billion board feet. The first concern of research, then, should be with the existing forest. We must determine what kinds of trees and stands should be cut first because we know from experience that sometimes selective logging is beneficial but sometimes it has only hastened stand deterioration. And the purposes of forest management are not satisfied by simply extracting the full value from existing timber. When the old timber is removed, the land must be promptly restocked if intensive forestry is to be practiced.

Also urgent is the problem of how to restore forest cover to brushfields which are capable of producing timber. Much research has been devoted to artificial forestation, and much has been learned, but we must admit that wholly satisfactory methods have not yet been developed. The review also has revealed that the research effort is not being distributed equally in proportion to the area and growth potential of the major forest types. For example, the Station has no research program in the redwood type despite the high productive capacity of redwood lands.

These are only a few of the highlights. Before the problem analysis is completed, many more subjects must be considered, including the opportunities for cooperative studies and which projects offer the best chances for positive and useful results in proportion to the effort required. Meanwhile, the 1952 program continued to stress the care of existing forests. All the major operations for a going

forest enterprise were conducted in the test of Unit Area Control management at Blacks Mountain Experimental Forest. New information was developed on a beetle epidemic in young sugar pine, on pruning, and on chemical control of undesirable vegetation. Some studies of forest regeneration were extended in scope or expanded to pilot-plant size. And some major projects reached the stage where their analysis can contribute much-needed information on forest growth and reproduction.

BLACKS MOUNTAIN STUDY DEMONSTRATES PINE MANAGEMENT

The Blacks Mountain Experimental Forest has been operated as a test-demonstration unit in pine forest management since 1937. Mature timber is harvested annually according to good silvicultural practices, cleared units are regenerated by whatever method seems most feasible, and the quality of the growing stock is being improved by pruning and other stand betterment practices. The ultimate purpose is to show how much and what quality timber can be produced under moderately intensive silvicultural management, and the costs and returns from these practices in the east-side pine type. The Bureau of Entomology and Plant Quarantine has cooperated closely in much of the timber marking because of the strong influence of bark beetles as a hazard in overmature eastside ponderosa pine-Jeffrey pine type.

In 1952, nearly 3 million board feet were harvested. Most of this cutting was conducted after the pattern of Unit Area Control. Eleven acres were clear cut for natural regeneration, 5 acres for artificial regeneration, and the remaining portions of three 100-acre compartments were given release and improvement cuts. Rodents were poisoned and seedbeds were prepared on the natural regeneration units.

The year 1952 provided our first chance to test insect risk marking while bark beetle populations are increasing. Marking for harvest the trees that appear most susceptible to beetle attack has proved highly successful in reducing insect losses under low bark beetle populations. This year insect losses rose to over 200 board feet per acre on uncut compartments held for tests during epidemic conditions. Therefore insect risk cuts were made in three 100-acre compartments which will receive no further cutting for 20 years while the results are measured. Also during 1952, 8,548 trees were pruned on 1,300 acres, and 14 acres logged in 1951 were planted with Jeffrey pine and ponderosa pine.

PRUNING RECOMMENDATIONS RESULT FROM TWO STUDIES

Analysis of 5 years' growth on pruned trees has provided some guides to the degree of pruning that is advisable in pine. In 1947, three degrees of pruning were used in an open stand of pole trees at Blacks Mountain Experimental Forest. Selected ponderosa and Jeffrey pine crop trees, with crowns averaging 86 percent of total tree height and an average diameter of 5 1/2 inches were pruned so that 25 percent, 50 percent, and 75 percent of the crowns were removed. At the end of 5 years, more than half of the trees with 75 percent of their crowns removed were dead, and the remainder of these trees had grown only .49 inch in diameter. Unpruned trees grew 1.64 inches; those with 25 percent of the crown removed, 1.68 inches; and those with 50 percent removed, 1.27 inches. On the basis of these results pruning up to 50 percent of the green crown is recommended for similar stands provided that at least .4 of the total height of the tree has live crown after pruning.

In another pruning study, at the Stanislaus Experimental Forest, new branches were observed sprouting from white fir trees one year after pruning. Analysis of the data from this study showed that these epicormic branches increased as: (1) More of the bole was exposed to sunlight by pruning; (2) the diameter of the trees at time of pruning decreased; (3) the growth rate of the tree increased; and (4) more of the green crown was removed. Consequently, it is recommended that no pruning of white fir be done until practical means of controlling the sprouting is found.

STUDY PROVIDES SOME CLUES TO BEETLE EPIDEMIC IN SUGAR PINE

A study of a mountain pine beetle epidemic in young sugar pine has offered some clues to how beetle attacks are influenced by the condition of the trees. About 5 years ago a mountain pine beetle outbreak began in a fine young stand of 40- to 60-year-old sugar pine on public and private timber lands in the Sierra National Forest. The losses have caused much concern to the managers and owners, partly because second-growth sugar pine is scarce and partly because bark beetles have been believed to be chiefly a pest of overmature timber. If mountain pine beetles can successfully attack immature sugar pine, they are a new hazard to sugar pine management.

An insect control program conducted in the infested timber in 1952 has reduced the immediate threat, but an answer was wanted to the question of why the outbreak occurred. As a result of conferences with the Bureau of Entomology and Plant Quarantine and the Sierra National Forest,

a cooperative study was undertaken. The Sierra National Forest collected data on the trees on 74 plots which aggregated 8.5 acres and contained 2,249 sugar and ponderosa pine trees as well as a good many additional trees of other species, chiefly white fir. Fifty-nine percent of the pine trees on the plots had been killed. The dead trees ranged from 2 to 30 inches in diameter.

The Station analyzed the data from the plots in an effort to find what relation might exist between the occurrence of successful attacks and the condition of the trees as measured by such factors as crown class and density of stocking. One of the more significant things observed from study of the data is that intensity of attack did not seem to be related to stand density. The number of trees per acre did not affect the percentage of the pine killed.

Although the data seemed to disprove that the beetle attack was influenced by stand density, further analysis showed that in the earlier stages of the outbreak, a larger percentage of the weaker trees were selected by the insects. Of the trees attacked by beetles and killed before the 1952 control operation, 76 percent were in the intermediate and suppressed crown classes. In contrast, of the trees attacked later -- which either still contained insects at the time of the control work or were first attacked in 1952 -- only 47 percent were from the intermediate and suppressed crown classes. The difference was found to be highly significant statistically.

The findings tend to confirm the theory that less thrifty trees are likely to be attacked first. They support the idea that silvicultural operations such as thinning from below may assist in preventing bark beetle epidemics.

COMPETING PLANTS HINDER GROWTH OF YOUNG TREES

Broadleaf shrubs and trees of little or no commercial value often seriously impede the establishment of conifer reproduction on California forest land. These woody broadleaf plants are long lived and many of them are not easily destroyed by fire or mechanical methods. For example, 50 clumps of madrone sprouts were measured one year after the tops of the parent plants had been killed by a hot slash fire. The regenerated plants were found to average about 15 sprouts to a clump, each clump being more than 4 feet tall and 4 feet across. Obviously the fire, though hot, had not seriously set back the madrones; they may even have been induced to spread somewhat.

How competing vegetation affects survival and growth of tree seedlings was shown by a test at Blacks Mountain Experimental Forest. This study was begun in 1948, when there was an excellent seed crop. Of the pine seedlings established naturally from this crop, 11,000 young trees per acre were alive in 1952 where the ground was free of competing vegetation. With a light ground cover of other vegetation, 1,300 pines per acre had survived, and less than 170 remained with medium to heavy cover. The average height of seedlings on the bare areas was 5.6 inches; on areas with light cover, 2.3 inches. Height was not significantly different on areas with light, medium, or heavy cover. That competing vegetation is an obstacle to artificial forestation, too, was illustrated by second-year survival of planted pines: Survival averaged 53 percent with very light ground cover, 43 percent with light, 34 percent with heavy, and 19 percent with very heavy cover.

HERBICIDES PROVE EFFECTIVE AGAINST COMPETING SHRUBS

The herbicides 2,4-D and 2,4,5-T are being tested on a wide variety of woody plants in several cover types, and under different conditions of application, in a search for surer and cheaper ways to eliminate the undesirable competition to small conifers. In one test upon Ceanothus cordulatus, started in October, 1950, two commercial adjuvants--a detergent and a waxy spreader--were added to 2,4-D and 2,4,5-T in an effort to increase the toxic effects of the spray. The 2,4,5-T proved to be much more toxic than 2,4-D but neither of the adjuvants enhanced the effectiveness of the herbicides. The average percents of resprouting or new growth on July 10, 1952 were:

Herbicide	Control	Detergent	Spreader
2,4,5-T	8	14	8
2,4-D	40	50	65

In another study, the influence of time of day and time of year upon effectiveness of the sprays was tested. In the test of time of day, in which chinquapin was the subject, the percents of resprouting or new growth 1 1/2 growing seasons after application were:

Time Sprayed	2,4,5-T	2,4-D
7:30 A.M.	12	26
9:30 A.M.	19	27
noon	16	63
2:30 P.M.	22	55
5:00 P.M.	20	21

With 2,4,5-T, which was more lethal, time of day had little influence, but with 2,4-D, midday spraying was far less effective. The time of year study employed 4 species, 5 dates, and 2 chemicals; hence the results are too complex to report in detail here. In general, 2,4,5-T applications were effective at all dates and for most species. Ceanothus parvifolius entirely failed to resprout. Arctostaphylos patula, Ceanothus cordulatus, and Castanopsis sempervirens generally resprouted less than 35 percent by the middle of the second growing season. The percent of resprouting by the middle of the second growing season after application of 2,4-D is shown below:

Date sprayed	Arctostaphylos patula	Ceanothus parvifolius	Ceanothus cordulatus	Castanopsis sempervirens
7/3/50	33	17	38	72
8/7/50	24	0	58	16
8/24/50	13	0	44	48
9/28/50	3	64	54	28
11/10/50	4	73	76	86

The findings in regard to the influence of time of year agree with similar observations reported by the Forest Fire Research Division. Studies of chemical sprays will be continued in 1953, and some new trials started, but it is already evident that the hormone-type sprays have much promise for elimination of several undesirable woody plants.

BETTER TECHNIQUES SOUGHT FOR SEEDING AND PLANTING.

Many past experiments in seeding and planting have demonstrated that besides competing vegetation, seed-eating rodents and unfavorable weather are sometimes serious obstacles to artificial forestation in California. Current research, therefore, is being directed largely toward eliminating practical difficulties. One difficulty is to protect tree seed from rodents at low cost. In 1951, some encouraging preliminary results with "K-screens" were reported. K-screens are small, inexpensive screen tubes that protect planted seeds from rodents and that do not need to be removed after seedlings become established. In 1952, the K-screens were tested in several forest types, including Douglas-fir, eastside ponderosa pine, and Sierra Nevada mixed-conifer. The results were quite generally disappointing, and on the basis of recent findings K-screens cannot yet be recommended for general application.

Another difficulty in artificial regeneration of the

forest stems from wide climatic differences between nursery and planting sites in the region. These differences often make it necessary to take nursery-grown trees from the ground and store them until weather and soil-moisture conditions are appropriate for planting. An experiment in storing nursery stock over winter gave good results in 1952. Ponderosa pine 1-1 stock which had been baled and stored 6 months was planted under uniform conditions, and two months after planting survival was:

	Storage Temperature		
Packing medium	36° F.	32° F	23° F.
	. . percent survival . .		
Vermiculite	98	71	0
Sawdust	79	81	0
Shingle tow	71	46	0
Peat moss	81	81	0

Evidently, with the right temperature and storage medium, overwinter storage, which has important advantages in large reforestation programs, is entirely feasible. Hence, in November planting stock was put into storage for a much larger pilot-plant size trial. This stock will be outplanted in 1953 and the results measured at the end of the growing season.

REGENERATION STUDIES EXTENDED IN DOUGLAS-FIR

Both artificial and natural regeneration studies were installed in the Douglas-fir type on the Trinity and Six Rivers National Forests. National Forest Administration supplied substantial cooperative aid. Cutting in the overmature, brushy Douglas-fir timber of California has begun only recently and it is evident that special methods need to be developed in order to insure satisfactory regeneration. The investigations which were started include seeding and planting of Douglas-fir and ponderosa pine in relation to slope and aspect, natural seeding, seedbed conditions, and control of woody broadleaf plants. The University of California is cooperating in studies of rodent population and control methods. These studies are expected to take a new turn in 1953 because for the first time since work began, a good Douglas-fir seed crop appears likely to occur. This will permit measurement of seed dissemination and, in the following year, measurement of natural reseeding on the study areas.

THREE MAJOR PROJECTS REACH ANALYSIS STAGE

Three long-time projects have been brought to a stage where they can aid materially in applied forestry. Analyzing these studies to date and publishing the findings will not only make useful information available to forest managers, but also indicate if continuation of the projects is desirable. One of the projects is determination of mortality factors for application to forest growth predictions. Mortality estimates are, at present, the most difficult part of net-growth determinations. Many long-time plot records are available for the analysis. It will be a big job and publication is not anticipated until 1954.

Another long-term project which is ready for analysis is the record of seed crops for several important species of trees. This information should be very valuable in harvesting and regeneration operations where reliance is placed upon natural seed fall. The information will also be helpful to seed users because it will help to indicate how much seed should be stored for use in years when forest trees produce no seed. Completion of this work may extend into 1954.

The third, and most difficult of the major reporting jobs is summarizing and interpreting the findings from the Blacks Mountain pilot-plant management project. This is a type of research for which there is comparatively little precedent. Evaluating and summarizing the information will be a challenge to the project workers. In the meantime, to help put findings of these projects to use, we will take advantage of several methods for transmitting whatever information we have--conferences, field training sessions, and demonstration on experimental forests and other study areas.

FOREST GENETICS RESEARCH

The scope of forest genetics research was broadened somewhat at the Station in 1952. During the past 10 years the Division of Forest Genetics has devoted most of its effort to developing and testing a well-defined breeding procedure. Primarily we have been crossing different species of pines, testing the promising hybrids, and conducting selective breeding tests among the hybrids and their progeny. This program has produced more than 70 different hybrid combinations, some of which have shown considerable promise in tests conducted in California and elsewhere. At the same time experience with this simple pattern of research has brought out the need for more comprehensive, fundamental studies to make the pine tree improvement program more

effective. Consequently some new studies were undertaken in 1952. Hybridization and field tests were continued, and in this work, too, we tried to emphasize specific objectives that would contribute to fundamental knowledge.

VARIATION IN WESTERN PINES SUBJECT OF NEW STUDY

One new study is on the natural distribution and variation of ponderosa pine, its hybrids, and closely related species. This study was made possible by grants from Mr. Fred Searls Jr., through the Forest Genetics Research Foundation. The trees to be studied make up a large, widely distributed complex of botanical and commercial importance. The complex includes several varieties of ponderosa pine and such closely related species as Jeffrey pine, Apache pine, Washoe pine, and Montezuma pine and perhaps other yellow pines of Mexico. One phase of this new project will be an inventory and appraisal of the many forms, or strains, of this complex growing in the Eddy Arboretum and in the Station's large plantations of ponderosa pine progeny from selected Sierra Nevada seed trees. Another phase will be the collection of desirable forms and hybrids for planting at the Institute of Forest Genetics and other readily accessible locations. Preparatory work on the study was done late in the year. Information obtained from the study should make it possible to breed for specific locations and purposes with far greater precision than is now possible.

DIFFERENT SELECTION BREEDING METHODS TO BE COMPARED

Another new study still in the preparatory stage is to test the practicability of different selection methods of tree breeding within a single species. This work will include the so-called "mother tree" selection, or natural progeny test. In this method the progeny is from seed-parent trees selected for certain outstanding characteristics, but pollinated naturally by unknown pollen parents. Much has been written about this method, and some large progeny tests have been established, including our 1929 and 1937 plantings of progeny from ponderosa pine seed trees. Results of these tests have so far been inconclusive, chiefly because statistical methods or biological controls--or both--have not been adequate. One of the first jobs to be done then, will be to eliminate these sources of error through use of small tests in which the necessary controls can be maintained more readily.

DISEASE RESISTANCE STUDIED IN WHITE AND YELLOW PINES

Contributions to fundamental knowledge were stressed in continuing the study of hereditary resistance to disease, and in expanding the study of oleoresin chemistry. Much of our work on disease resistance is being conducted as part of an international research program seeking to develop trees resistant to the white pine blister rust disease. In this integrated attack on one of North America's worst forest tree diseases, many agencies are cooperating, including the Division of Forest Pathology, Bureau of Plant Industry, Soils, and Agricultural Engineering; the Division of Plant Disease Control, Bureau of Entomology and Plant Quarantine; the University of Wisconsin; the Northern Rocky Mountain Forest and Range Experiment Station, other experiment stations, and National Forests of the U. S. Forest Service; and the Department of Lands and Forests, Province of Ontario, Canada. The program includes selection of naturally resistant trees, development of propagation methods, studies of the disease and its alternate host the Ribes shrubs, and production of resistant hybrids. Each agency works on the problems it is most familiar with, according to a previously agreed upon plan.

As part of this cooperative program, the Institute of Forest Genetics has been grafting shoots from selected rust-resistant trees on root stocks from other pines. In 1952, 40 grafts made with scions of Western white pine selections sent to the Station from northern Idaho, were planted out at the Institute. One purpose of this planting is to compare the growth of single selections on root stocks of several other pine species. The planting also will provide material for future breeding work. Grafts of Macedonian pine (Pinus peuce), a rust-resistant European species, and of a hybrid between Macedonian pine and Eastern white pine, were received from the Canadian experiment station at Maple, Ontario. These were also planted at the Institute.

In another planting at the Institute, 240 ponderosa pine seedlings were set out for the purpose of studying the inheritance of resistance to Cronartium harknesii, a rust disease of the hard pines. These seedlings represented three different progenies from the same rust-resistant ponderosa pine seed tree. Two of the progeny types were produced by hand pollination using pollen from a susceptible ponderosa pine and from another resistant ponderosa pine. The third type is from natural pollination by wind-borne pollen of unknown source. This test is being conducted in cooperation with the Division of Forest Pathology, Bureau of Plant Industry, Soils, and Agricultural Engineering,

which will make artificial inoculations of the disease when the seedlings reach the proper age.

BIOCHEMICAL RESEARCH ANALYZES NEW SPECIES

Research on the chemistry of pine turpentines was expanded with the aid of the Rockefeller Foundation's grant to Dr. N. T. Mirov, mentioned in our 1951 report. This grant permitted employment of a chemist assistant, and systematic analyses of turpentines continued throughout the year without interruption. A noteworthy discovery resulting from these analyses was that of a heptane-containing pine in Chiapas, Mexico. The taxonomic position of this pine is as yet uncertain. Another interesting suggestion arising from investigation of Mexican pines is that P. Durangensis, which once was regarded as a synonym for ponderosa pine and later placed with Montezuma pine, apparently deserves rank as an independent species.

Oleoresins of the following pines were analyzed: Pinus cooperi, from Durango, Mexico; Pinus durangensis, from Durango, Mexico; Pinus oocarpa, from Michoacan, Mexico; Pinus pinceana, from Chiapas, Mexico; Pinus pseudostrobus var. oaxacana, from Chiapas, Mexico; Pinus reflexa, from Arizona; and Pinus resinosa, from Wisconsin.

This oleoresin study was extended to include an investigation into the inheritance of turpentine constituents from species not heretofore studied. Oleoresin was collected from natural hybrids between lodgepole pine and jack pine, which had been found growing in Canada near Edmonton, Alberta. The study has been augmented by turpentine analyses of the first generation hybrids produced by artificial crossing of the two species. The natural hybrids of Canada and the artificial ones at the Institute thus offer an excellent opportunity to study the inheritance of chemical characters in pine hybrids.

This biochemical work may have an important bearing on breeding for disease and insect resistance, for cooperative studies by the Forest Insect Laboratory, Bureau of Entomology and Plant Quarantine, suggest that the resistance of certain pines to bark beetles may be related to the chemical composition of oleoresin.

Some chemical work also was done on the biology of flowering and seed production in pines. Knowledge of these subjects is second only to knowledge of genetic principles in importance to our program. Facilities and personnel for this study are limited, and the main work in 1952 consisted of injecting flower-promoting and growth-promoting substances into pine trees. The purposes of these small-scale tests are to

develop effective injection techniques. These techniques then can be used in more intensive studies of ways to change the metabolism of pines by injecting organic and inorganic nutrients, auxins, and antibiotics.

HYBRIDIZATION ATTEMPTED WITH 49 PINE SPECIES

In its work of exploring and exploiting the genetic variability of the pines, the Division attempts some new or repeat crossings each year. In 1952, the hybridization program amounted to 580 pollination bags which enclosed about 1,715 conelets. Forty-nine different species combinations were attempted, and 43 of them were new attempts, including: 30 first-generation crosses, 4 backcrosses, 7 three-species crosses, and 2 four-species crosses. Thus, almost one-third of the new crossings used hybrids as one of the parents. As more and more hybrids come into flower bearing, the percentage of such crossings will increase.

This recent work with hybrids illustrates rather well the possibilities of the breeding process. For example, in one bag which contained 2 cones, 237 sound seeds were obtained from the cross of ponderosa pine on the Jeffrey-Coulter backcross hybrid--P. jeffreyi x (P. jeffreyi x P. coulteri). The high yield of sound seeds per bag is particularly noteworthy in this instance. Ponderosa pine is highly susceptible to the pine reproduction weevil (Cylindrocopturus eatoni). Coulter pine is resistant to that destructive insect. Thus, the combination offers the possibility of getting a vigorous resistant hybrid of high quality to plant where the weevil is a hazard to reforestation with ponderosa pine. The implication is that such a tri-species hybrid might have some of Jeffrey pine's cold resistance, some of Coulter pine's exceptional juvenile vigor and resistance to drought and the weevil, and some of the sustained vigor and good wood quality of ponderosa pine. Separate tests of the hybrid for these different characters are desirable. This instance of high fruitfulness on the part of a young backcross hybrid suggests that such tests may soon be underway.

It is worth observing that this cross might well be but a very early phase of a much more elaborate process. Thus, on the basis of present knowledge, the next step will probably be to inject some Apache pine (P. latifolia) genes into the mixture in order to speed up root-development and diameter-growth. Carrying the speculation further, admixtures of Mexican species and of any of the so-called southern pines might in time give rise to a composite form, adapted to a very wide variety of conditions.

NEW HYBRIDS RESULT FROM EARLIER ATTEMPTS

Some new hybrid combinations are growing in the 1952 nursery tests as a result of crossings attempted in previous years (table 1). Among the hard pines are four new southern pine crosses, including one between slash and longleaf pines which is a reciprocal of a cross made long ago at the Southern Forest Experiment Station of the U. S. Forest Service. A new western hard pine hybrid is the backcross of a natural Jeffrey-Coulter hybrid to the more-vigorous Coulter pine. This backcross shows exceptional vigor at 1 year of age. It is superior to a backcross to the Jeffrey pine parent and superior to natural progeny of this parent, but probably is less cold resistant.

Among the new soft pines are four hybrids between the blister-rust resistant Himalayan white pine and other species. The hybrid between Mexican and Himalayan white pines has been reported to occur spontaneously in the Kew Gardens of England and was named Pinus holfordiana. The other three are reciprocals of hybrids previously made at the Institute of Forest Genetics. The cross with Eastern white pine is a reciprocal of the hybrid which has shown considerable resistance to white pine blister rust during 7 years growth in a heavily infested test plot.

Table 1.-New hybrid pines at Institute of Forest Genetics, 1952 nursery.

Hard Pines	
Seed parent	Pollen parent
Jeffrey x Coulter hybrid	Coulter pine
Shortleaf x loblolly hybrid	Slash pine
Shortleaf x loblolly hybrid	Loblolly x slash hybrid
Loblolly x slash hybrid	Slash pine
Slash pine	Longleaf pine

Soft Pines	
Seed parent	Pollen parent
Mexican white pine	Himalayan white pine
Himalayan white pine	Limber pine
Himalayan white pine	Western white pine
Himalayan white pine	Eastern white pine
Western white pine	Limber pine

In the older nursery tests, hybrids produced by using the same lot of Eastern white pine pollen on two varieties of Western white pine provided an interesting comparison. This test is now 4 years old. Hybrids of a Western white pine seed parent from Idaho have consistently outgrown those of a Western white pine seed parent from California. Similarly, natural progeny of the Idaho parent outgrew that of the California parent. Thus these results suggest that hybridization may often be done so as to bring out differences in characters of one of the parents which are associated with geographical differences in habitat. Similar results have been obtained by the Maria Moors Cabot Foundation for Plant Research in working with poplars.

MORE FIELD PLANTINGS MADE WITH HYBRIDS

Additional field plantings were established in 1952 to obtain information about the performance of promising hybrids and other pedigreed forms on different sites. These plantings serve other purposes as well as performance testing. They provide materials for future breeding work. If the same forms are planted far enough apart latitudinally, valuable information regarding photoperiod response may be obtained from the tests. Such information might have a special bearing on the biology of flowering and on other important phenomena. The test plantings may also become valuable seed farms.

Small field tests of 24 hard pine and 12 soft pine hybrids were established at the Institute of Forest Genetics. Of them, 16 hard pine and 9 soft pine hybrids had not previously been used in field plantings at the Institute. The hard pine group included 10 crosses in which one of several different geographical races of ponderosa pine had been used as one of the parents. Two of these were backcrosses of Jeffrey and ponderosa pines to the Jeffrey-ponderosa hybrid which has proved highly resistant to the western pine beetle in tests by the Forest Insect Laboratory. The soft pine group included several foreign pines: hybrids between sugar pine and Armand and Korean pines and some between our Eastern or Western white pines and species from Asia, Europe, Mexico, and Japan.

Large field tests of hybrids were established on the Eldorado, Stanislaus, and Tahoe National Forests. In these tests, the hybrid stocks, which were grown at the Forest Service Shasta Nursery from seed supplied by the Division, were interplanted with appropriate natural progeny of parent species as checks. The hybrids used in these tests are:

Seed parent	Pollen parent
Jeffrey pine	x (Jeffrey pine x Coulter pine)
(Jeffrey pine x ponderosa pine)	x Ponderosa pine
Sierra Nevada ponderosa pine	x Apache pine
Sierra Nevada ponderosa pine	x Arizona ponderosa pine
Sierra Nevada ponderosa pine	x Rocky Mountain ponderosa pine

Smaller field tests were established with the aid of various cooperators at Chester and Nevada City.

It is worth observing that there are now at our Institute of Forest Genetics almost as many different hybrid combinations as there are different species of pines. Within a few years, the number of hybrids will probably be larger. Most of these hybrids are likely to prove fairly fertile--many have already exhibited fertility. If this prediction is borne out, the pine-breeder of the future will have a much greater breeding scope than do the present staff members. Yet it seems likely that capitalizing on this opportunity will require expansion of forest genetics research. The hybridization work and other activities mentioned in this report make up a research program that imposes a very heavy load on the present staff. Other important studies are needed to round out the program. They include cytological studies of hybrids and aberrant forms, vegetative propagation, physiological and biochemical aspects of disease and insect resistance, chemical analyses of pine rosins, barriers to crossing between species, self-compatability of pines, and the occurrence and effects of natural selfing in various species.

FOREST FIRE RESEARCH

Seeking ways to control and use fire more effectively in wild-land management, the Station's fire research staff emphasized two broad fields of work in 1952. One was the field of evaluation, for which progress was recorded in determining damages that result from fire and in measuring the severity of fire danger in different years and areas. The other field was in providing aids to the men who must control fires. This work included development of simple field aids, tests of brush eradication on fire trails and roads, studying of training methods in use of water, and analysis of methods of organizing fire-fighting forces.

The Station's fire research staff also participated in

the work of a special research group, assigned to the Station for administrative support, in a program of studies directed by the Washington Office of the Forest Service. This group has contributed valuable information on the thermal properties of forest fuels and on fire behavior.

FIRE DAMAGE EQUATION DEVELOPED FOR TIMBER

In the continuing study of ways to appraise fire damages, emphasis in 1952 was given to study of the timber resource. The chief question was: what principles should guide appraisal of timber damage? Principal among these, we have concluded, is the concept used by the courts in damage claims; that is, the value as replacement in worth and not necessarily in kind. This concept is essential if the damage appraisal method is to have universal application and acceptance in determining both the need to protect natural resources from fire and the ways to use fire for possible beneficial purposes.

In applying this concept to timber-damage appraisal, fire damage is considered as the difference between the capitalized net value of the area for timber production before burning and the capitalized net value after burning. Maximum damage, therefore, will depend on the productive capacity of the site and the length of time that capacity is reduced by fire. The principles developed have been formulated into a general equation expressing fire damage to the timber resource. In its present form the equation is too complex for field use, but we believe it will provide a sound basis for development of simpler procedures. Tests of the general equation have been started, using both idealized and actual situations. This is a necessary step to check applicability to a wide range of field conditions. A similar general equation for appraising damage to the range resource has also been developed. The preliminary range appraisal system developed in 1951 will be modified to incorporate these new ideas.

One of the most difficult forms of fire damage to evaluate is that done to recreation values. The literature shows that several methods have been used in attempts to evaluate recreation. None found so far are free from one or more serious weaknesses. The basic difficulty appears to lie in trying to place a dollar value on a man-day of recreation.

EFFECTS OF WILDFIRE STUDIED IN TIMBER, RANGE

Field studies of the effects of fire on range and timber resources were continued. In one series of these annual measurements have been made of plots in a perennial range type on the Shasta National Forest burned by wild fire in 1949. They show that serious loss of forage occurred. For example, the fire completely eliminated the predominate browse species, bitterbrush (Purshia tridentata). Three years after the fire the total ground cover of palatable perennial species is only about 3 percent of that before the burn. Cheat grass (Bromus tectorum) and other weed species are increasing rapidly.

Another field study is being made to collect quantitative data on fire-induced erosion. About 125 plots have been established on forest and range wildfires of the last three years. These are re-measured annually to determine the susceptibility of different soils to erosion and to establish the rates at which vegetation recovers in different soil and plant types. Observations thus far indicate that both sediment damage and site deterioration from loss of top soil following fire may be far greater in some parts of northern California than generally supposed.

Plans for 1953 are to further explore the recreation damage problem and to complete the appraisal systems for timber and range resources and submit them for critical review. Both field and office studies of erosion and ways of evaluating its damages will be continued.

NEW ANALYSIS MADE OF FIRE DANGER INDEX

Additional information was brought into the analysis of fire danger rating and the size and occurrence of fires on selected rating areas. A preliminary analysis of these conditions had been made in 1951 to provide a comparative measure of fire season severity against which to judge fire control accomplishments. One finding of the analysis was a lack of uniformity in the way fire danger varied between areas from season to season.

To help find causes for the variation--and also to provide a more representative base on which to evaluate season severity, the analysis was extended to include 2,100 fires in 48 rating areas for the period 1945-51. This analysis related number of fires per day and average size of fire to the fire danger rating. By using these two relations it was possible to compute a "probable" acreage burned for each day in the fire season for any fire danger rating area. A comparison of the totals for each season thus gave a

comparison of the relative severity of the season. To simplify comparisons the ratio of probable acreage burned in each year to the 1945-51 average was computed. This has been called the "fire season severity index."

Considerable variation was still noted among the indices of the danger rating areas, frequently even between adjacent areas. Study of these differences showed a tendency for rating areas to group themselves in individual years by latitude, by altitude or general aspect. The grouping varied by years, suggesting that fire danger variations among areas are controlled by large scale weather phenomena. Just what these are, how they are brought about, and what their true significance is can be answered only by further studies.

HUMIDITY INDICATOR PASSES FIELD TESTS

During the year the staff worked on two simple aids to fire fighters, a humidity indicator and a fire danger guide. This year's field experience with the chemical humidity indicator designed in 1951 suggested the need for some changes. This device, adapted from types used in industrial operations, consists of a paper card on which a series of spots are impregnated with solutions of cobaltous chloride of various concentrations. The spots change from blue to pink as humidity increases.

A field test of the practicability of the indicators was made during the 1952 fire season by distributing 260 cards to State and Federal fire control workers. A questionnaire attached to each card requested information on its use, practicability, and accuracy, and other comments. By year's end 30 percent of the questionnaires had been returned. Of these, 73 percent commented favorably, 12 percent unfavorably, and 15 percent undecided or did not use. After some changes in design--such as providing a color check spot for more uniform interpretation of color change, a more durable carrying case, and better instructions--it appears highly probable the indicator will have wide field use. The card may also be susceptible to further development as an effective fire prevention tool. The indicators can be supplied commercially to practical field specifications at reasonable cost for large quantities.

The fire danger guide was prepared for the East Bay Hills fire control organizations. It consists of six pages of simple tables giving indices of rate of spread and guides for interpretation of the indices.

BETTER USE OF WATER SOUGHT IN TRAINING STUDY

Work on use of water for fire suppression was aimed chiefly at developing a training program for fire crews. Information is not yet complete on just what constitutes the most efficient techniques and equipment for application of water. Past studies and observations of fire crews in action, however, have indicated that present knowledge and equipment are not often used efficiently. As a result water is wasted and not enough fire is put out.

Effort in 1952 was therefore concentrated on finding ways to increase the performance level of fire fighters. Specifically, we are trying to develop a training program with suggested teaching aids suitable for seasonal tanker crews. Work thus far has been concerned with survey of water use in the western states, gathering information on various teaching methods appropriate to the job, and making preliminary analyses of the principal tasks and procedures that constitute tanker-crew practice in fighting fires. The Shasta National Forest made two tanker crews available to the Station for the summer months. Both crews helped make job analyses, demonstrated individual steps in fire-fighting action, and offered comments and suggestions on training methods and devices. The foremen of these crews were college students with one year's tanker-crew experience.

The next phase of the problem probably requires more administrative than technical study. We need answers to such questions as: What level of performance is the administrative organization willing to accept? To what extent is training recognized as a specialty and appropriate instructors selected and developed? How much training time can be afforded? The answers will largely determine the nature of the suggested training program.

ROADSIDE TESTS CONTINUED WITH CHEMICAL SPRAYS

Studies of chemical methods for controlling brush as a road maintenance measure were continued. Fifteen plots were treated with new formulations of 2,4-D and 2,4,5-T on the Shasta and Six Rivers National Forests. Pilot testing of herbicides on roadside brush was also continued with Shasta National Forest personnel. About 200 miles of road were sprayed, including retreatment of approximately 75 miles first sprayed in 1950 and 1951.

The pilot study has shown, among other things, that some troublesome brush species have only a critically short period of susceptibility to 2,4-D and 2,4,5-T sprays during their seasonal growth cycles. This period differs between

years. Studies conducted by the Division of Forest Management Research have also indicated that time of year influences the effectiveness of spraying. In mountainous country the period of susceptibility also differs with both altitude and aspect. Since individual roads often traverse topography with wide differences in both, the problem of scheduling treatments for optimum results is complex. On a field scale operation it is thus not practical to achieve optimum timing everywhere. Some retreatment will always be necessary, but the good manager can keep it at a minimum by good on-the-ground planning. The study continues to demonstrate the paramount importance of 100 percent coverage of the sprayed vegetation.

NEW APPROACH PROPOSED FOR FIRE ORGANIZATION

Early in 1952 the fire research staff made a detailed study of the organization plan set up by the California Region of the Forest Service for suppression of large fires. The results were submitted to the Region in the form of suggestions for inclusion in a current revision of the existing plan. Some of the suggestions were incorporated. Later in the year a different form of organization plan was submitted to both the Regional and Washington offices of the Forest Service for consideration in the development of a uniform plan for all western Regions. This plan represents the results of several years' study and experience with organization problems in controlling large fires.

The plan submitted differs from those generally used in several respects. It recognizes that two distinct types of jobs must be dealt with. One type consists of "thinking" jobs--getting and analyzing information, planning fire-control action, and giving overall direction to the suppression task. Other activities are essentially "doing" jobs--fighting fire and servicing the organization. The plan separates these two types organizationally and physically. It divides the management job into homogeneous parts small enough that each can be given the required attention by a responsible person. It provides a system of automatic checks and balances aimed at minimizing human errors and failure to carry out assigned tasks.

The principal feature of this plan is that the three interdependent jobs that make up overall fire management are set up as a management triumvirate having a single outlet for communication with fire line and service forces. The Fire Boss has overall responsibility. Supporting him are the coordinate units, Information and Planning. To insure unity of effort, the three work together at a Control Center, the heart of the management triumvirate, through

which all incoming and outgoing information, orders, and instructions flow. The Control Center is under supervision of Information. Cross checks on performance and accomplishment are provided by assigning primary responsibility for inspection of all activities but its own to Information, with its activity in turn checked by the Plans unit.

SPECIAL PROJECT YIELDS BASIC FIRE KNOWLEDGE

New knowledge of the physics and chemistry of forest fires was contributed by the special fire research group working at the Station. One fundamental phase of this work has been concerned with the thermal properties of forest fuels. Forest fuels are heterogeneous mixtures of a number of green and dead organic substances. Fuels which exert the greatest influence on forest-fire inception and spread include dead leaves, grass, conifer needles, moss, bark, wood, and charcoal; and with the exception of charcoal these materials are in various stages of decay or decomposition. Thermal properties of these common forest fuel types have not previously been investigated in a thorough manner because of lack of funds and personnel. Furthermore, laboratory studies of thermal conductivity and other properties hitherto have been considered extremely difficult because of fuel shape, size, and structure.

One study determined thermal conductivity of a number of hardwood-leaf and rotten-wood specimens by modifying their specific gravity and form so that measurements could be made by a thin plate uni-directional heat flow method. Analysis of these results showed them to be compatible with the linear relationship between thermal conductivity and specific gravity of wood developed originally at the Forest Products Laboratory by MacLean. Conclusions were that conductivity of common forest fuels may be determined from their specific gravity by application of MacLean's equations, and that MacLean's equations may be applied generally to most vegetable fibrous materials.

Another study was concerned primarily with thermal properties of forest fuels as they influence ignition and initial combustion as well as subsequent fire behavior. In addition to summarizing some current experimental data, a theoretical analysis was made of the net heat required for ignition. Designed for use of other investigators in this same field, the study includes:

1. Equilibrium moisture content curves applicable to heating of wood as a desorption process;

2. Analyses which indicate the possibility that wood may have two specific heats depending on whether temperature of the wood is decreased or increased during measurement;

3. Correlations of variations in heat of decomposition as determined by various investigators which indicate that heat of decomposition decreases with time of heating, becoming a negative heat yield approaching latent heat of vaporization as time of heating approaches zero;

4. Measurements of specific gravity and determination of thermal conductivity for 28 common fuels;

5. Brief description of effect of dimension and structure of combustible material and measurement of mean thickness of 29 common fuels, and,

6. Measurements of absorptivity of some grass and hardwood leaf fuel specimens.

A number of fire behavior studies have also been made in cooperation with Fire Divisions of other Experiment Stations and other workers. The research group assisted a graduate student in making basic field studies of atmospheric stability conditions. This work indicated that measurement of temperatures and humidities to heights of 2,000 feet is best accomplished using wiresonde and captive balloon techniques. A Friez Aerometerograph proved unsatisfactory, and a hand-held thermometer failed to provide sufficiently accurate information below 300 feet altitude. Work in progress in cooperation with the Southeastern Forest and Range Experiment Station, is aimed at determining relationships between atmospheric stability and fire behavior, developing stability criteria, and correlating these criteria with observed fire behavior.

Other upper air conditions than stability are quite likely to be associated with fire behavior. Recent Station effort therefore has been devoted to encouraging more active research and broader analyses in upper air studies.

Traditionally, fire behavior has been related to fuel, weather, and topographic conditions. Analyses of conflagrations, fire storms, and "blow-ups" indicate that

a fourth major factor--pattern and spacing of ignition--is also important in the development of these mass fires. Igniters and grenades were developed in cooperation with the Range Research Division, for electrical and delayed action fuse detonation. Using these, any pattern and spacing of ignitions can be obtained for detailed study.

Tests using igniters and grenades in controlled burning have also been made in cooperation with the Northern Rocky Mountain Forest and Range Experiment Station and our Division of Range Research. These indicate that igniters and grenades are useful for controlled burning and backfiring operations primarily in light fuels where ignitable material is on the ground. Men can be kept out of dangerous places, large volumes of fire can be built up quickly, and more effective burning out can be accomplished under poorer but safer burning conditions.

FOREST ECONOMICS

Information on the nature and extent of forest resources in California, urgently needed to help guide management of the resources, was gathered by the Division of Forest Economics. In this effort, we concentrated on two lines of work. One was the region's first statistically designed Forest Survey, now rapidly nearing completion of the basic inventory. The other was the vegetation-soil survey being conducted in cooperation with State and other Federal agencies.

FIELD WORK COMPLETE FOR TIMBER INVENTORY

The Forest Survey is a study being conducted by the U. S. Forest Service to maintain an accurate inventory of the Nation's forest resources. In California, we started this work in 1946. The procedure here is to map the different kinds of vegetation on aerial photographs, determine the area of each kind, and then measure sample plots in each kind to obtain information on timber volume, quality, and rate of growth, and on the amount of timber harvested or lost through fire, insects, and disease. A cooperative study by the U. S. Bureau of Agricultural Economics is providing additional information on forest land ownership. By the beginning of 1952, field work on the timber inventory had been completed for the North Coast Range and the western Sierra Nevada, and forest statistics had been compiled for the Coast Range Pine Subregion and several individual counties.

During 1952, a report on that subregion was published, giving in detail the statistics summarized in our 1951 annual report, and the job of measuring timber volume and growth on sample plots in the Sierra Nevada was finished. Thus, field sampling has now been completed for all major forest areas. This work, together with the results of aerial photo interpretation, provides the basis for computing final inventory statistics. Timber volume computations were completed for the Redwood--Douglas-fir Subregion on the western slopes of the Coast Range. Data from sample plots in the Westside Sierra Pine Subregion were coded and recorded on punch cards. Net volumes per acre were computed for different classes of timber, and at the end of the year these average volumes were being tested for statistical significance.

TIMBER VOLUME, GROWTH REPORTED FOR REDWOOD-DOUGLAS-FIR AREA

Among the major findings of the year were the results of computations for the Redwood--Douglas-fir Subregion. Preliminary Survey figures show a total commercial forest area of 4.2 million acres with a timber volume of 137.6 billion board feet (International 1/4-inch rule.). Nearly one-half the area and two-thirds of the volume are in old growth stands. Douglas-fir (79.0 billion board feet) and redwood (38.8 billion board feet) are the principal species, accounting for 85 percent of the total volume.

Comparison of these figures with those prepared for the 1945 Reappraisal report show that the acreages of commercial forest land are in close agreement, but that the Forest Survey volume estimate is about 50 percent higher than the Reappraisal figure. Most of this difference is due to the increase in the volume estimates of Douglas-fir and other "whitewoods." The volume of redwood showed very little change. The large increase in "whitewood" volumes is attributed to the fact that before World War II, timber operations in this area were largely confined to redwood. There was little demand for Douglas-fir. Consequently, the timber cruises of this period, which provided the basis of the Reappraisal volume estimates, frequently omitted Douglas-fir or included only trees containing logs of peeler quality. Since the war the value and volume of Douglas-fir have been more fully appreciated, and many new plants have been built to utilize this species.

The average annual growth for commercial forest land in the subregion was 385 board feet per acre. Mortality losses amounted to 134 board feet per acre, leaving a net growth of 251 board feet per acre. The high timber growing

potential of this subregion is indicated by the fact that the net annual growth of well-stocked second-growth stands averaged better than 1,000 board feet per acre.

SURVEY SHOWS LUMBER PRODUCTION AT NEW HIGH

In 1952 we also completed a survey of lumber production and source of logs in California and Nevada. This survey, made in cooperation with the Bureau of the Census, was the first of the 5-year periodic surveys required for the Forest Survey. For this job we supplemented the 1951 Census survey to obtain additional information on production by species, mill-size classes, and source of logs. The survey was limited to the lumber industry because products other than sawlogs had been adequately sampled the previous year as part of an equipment-manpower survey for National Defense agencies.

In this cooperative survey the Bureau of the Census provided information on the 170 mills in the Census sample. The Station compiled a complete listing of all operating sawmills in California and mailed questionnaires to the 630 mills not covered by the Census. Returns were received from 80 percent of these mills. An estimate of the production of non-responding mills was obtained by visiting a representative sample of the non-respondents. Altogether, reports were obtained from 93 percent of the mills in California. These mills produced 98 percent of the State's lumber production. Complete coverage of the 5 mills operating in Nevada was obtained by the Intermountain Forest and Range Experiment Station at Ogden, Utah.

The survey showed that California lumber production in 1951 amounted to 4.8 billion board feet, exceeding all previous records. Nevada's production of 26 million board feet was the highest in 80 years. For the first time Douglas-fir supplanted ponderosa pine as the leading species in California production. The volume of lumber produced in California from the major species was:

Species	1951 production billion bd.ft.	Percent of total
Douglas-fir	1.6	33
Ponderosa pine	1.2	25
Redwood	.9	18
True firs	.7	15
Sugar pine	.3	7
All others	.1	2
Total	4.8	100

Production of ponderosa pine, sugar pine, and redwood lumber in 1951 showed little change from previous years. Douglas-fir production increased nearly 50 percent and true firs over 100 percent since 1949. Humboldt County was the leading lumber producing county in California, accounting for 25 percent of the State total. The findings of this lumber production survey were published in December.

TIMBER USE BY MINES DECLINES IN REGION

We also completed field work and published a report on the use of forest products in underground mines in California and Nevada. The latest previous estimate of timber use in this industry was made in 1935. In 1951, California mines used 337,700 cubic feet of round and hewn timbers and 3.9 million board feet of lumber and sawn timber. Comparison of these figures with earlier estimates indicates substantial declines in both ore production and timber use in the last three decades.

RESOURCE INFORMATION FINDS READY MARKET

The need for basic resource information is indicated by interest in the statistical report for the Coast Range Pine subregion, published in April. Over 1,200 copies of this report were distributed to meet requests of lumber companies, utilities, county and state agencies, and others interested in the timber resources of this area. We plan to publish the report for the Redwood--Douglas-fir Subregion in 1953. Reports giving detailed information on forest area and ownership were published for Sonoma and Lake Counties, and others for Humboldt and Del Norte Counties were ready for publication by the end of the year. In addition to requests for published reports, the Division receives and replies to a steady flow of requests for survey information. These inquiries, averaging from 15-20 each week, range from requests for timber stand maps of specific areas to requests from public planning agencies for detailed data on forest land, timber resources, and industrial outlook for counties or watersheds.

VEGETATION-SOIL MAPS FILL NEED IN STATE

By July of 1952, results of the vegetation-soil survey being done in cooperation with the State of California included new aerial photography covering 7.3 million acres, improved base maps covering 1.3 million acres, detailed maps of timber stands on nearly 11 million acres outside the national forests, and detailed maps of vegetation and associated soil on about 3 million acres in Mendocino County and portions of bordering counties. Other material has been tabulated to show the relative productivity of different areas for timber and grass.

These results have evidently filled a need. Made available at the cost of reproduction, the map sheets and tabular material have sold steadily since 1949. About 15,000 timber stand maps and 2,000 vegetation-soil maps have been sold so far. Purchasers include lumber companies, livestock ranchers, real estate operators, timber consultants, banks, insurance companies, and county assessors. Many of the sales were to representatives of out-of-state forest industries seeking to locate in California. Another evidence of the need for this information is the recommendation of the State Board of Forestry, made late in 1952, that the State Legislature support an extension of the project. The Board recommended a long-range program of vegetation-soil mapping, to cost an estimated $77,000 a year and eventually cover more than 20 million acres of tree- and shrub-covered wild lands.

Field work on the vegetation-soil survey was brought to a halt in mid-year, as was required by the decision of the State Legislature in 1951 to postpone further mapping. The Station has been conducting this project since 1947 in cooperation with the California Division of Forestry and with assistance from soils technicians of the University of California and the U. S. Bureau of Plant Industry, Soils, and Agricultural Engineering. State appropriations for the work have totalled $373,000, and Humboldt County contributed an additional $8,000.

VEGETATION-SOIL SURVEYS MADE FOR NATIONAL FORESTS

A vegetation-soil survey started in 1951 for the California Region of the U. S. Forest Service was completed for an area of about 300,000 acres on the Mendocino National Forest. The end products, 16 sheets each of the timber stand and vegetation-soil maps, and accompanying legend sheets, have been turned over to the Mendocino Forest.

Another project financed by the Forest Service covered 140,000 acres within the Pit Soil Conservation District. This is one of the pilot districts being established in each state to work out and demonstrate a coordinated land management and conservation plan for both public and private lands. The Soil Conservation Service undertook to gather the physical survey data on the private land outside the National Forest boundary; the Bureau of Land Management agreed to survey all lands inside public domain boundaries; the Forest Service agreed to survey all lands inside the National Forest boundary. The Station mapped vegetation and soil on the area of Forest Service responsibility according to the same standards used in the cooperative State survey. But to enable conversion of field data into Soil Conservation Service land capability

classes, we also recorded erosion classes and aspect of topography. From these data four broad classes of land having different management potentials were defined, as follows:

1. Lands suited primarily for timber production.

2. Lands suited primarily for forage production.

3. Lands suited primarily for dual production of timber and forage.

4. Lands suited primarily for wildlife production and watershed.

We plan to map during 1953 two additional areas in the Mendocino National Forest. One area includes 75,000 acres in Colusa County, to be financed entirely by the California Region of the Forest Service. The second includes 240,000 acres in Glenn County. This job will be financed in part by the Forest Service, and in part by the University of California. The work will be done in connection with an overall soil survey of Glenn County that the University is conducting.

Meanwhile, the California Region of the Forest Service is proceeding to demonstrate how a vegetation-soil classification can lead to sounder land management. The Mendocino National Forest has already developed a management plan for one drainage unit of the 300,000-acre mapped area and has started a program of brushland improvement under this plan. Management plans are being prepared for other mapped drainages with the help of the Station's staff man that did the mapping. Two Forest Service committees, one of Forest Supervisors and one of Assistant Regional Foresters, have been set up to evaluate this Mendocino National Forest pilot study and to prepare a report on the value of the vegetation-soil survey to the management of the National Forests.

The Station also conducted a soils school on the Mendocino National Forest with the assistance of members of the University of California and the U. S. Department of Agriculture Division of Soil Survey, who have cooperated in the wild land mapping project. About 40 Forest Service men from the National Forests and the Regional Office attended. This school like previous ones held for county officials and employees of the State Division of Forestry, is evidence of a growing trend toward integrating basic soils knowledge into wild land management.

FOREST UTILIZATION SERVICE

Increasing needs for technical information in California's wood-using industries were served by the Station's Forest Utilization Service, a two-man unit with a two-fold objective. Through this unit's work we seek first to determine the regional problems on which research in wood utilization is needed and suggest such research to the U. S. Forest Products Laboratory at Madison, Wisconsin, or other research agencies; and second, to bring technical knowledge and results of research to the interested industries and wood users. The demand for information has increased not only because of increased lumber production, but also because of growing diversification of products from forest industries.

The report of the Forest Economics Division shows that the lumber cut in California in 1951 was the highest on record. The most striking change has been the greatly increased importance of Douglas-fir, white fir, and California red fir. At the same time the plywood industry has assumed an important position in the State. The production of logs and bolts for this use increased from 15 1/2 million feet in 1946 to 142 1/2 million feet in 1950. In the redwood region it rose to 93 1/2 million feet in 1950, there being no plywood production in that area until after 1946. In the pine region production rose from 15 1/2 million to 49 million feet in this same period. Pulpwood production has also increased, from 2 1/4 million feet in 1946 to almost 49 million feet in 1950. Of this, over half was Douglas-fir and one-fourth was redwood.

NEW INFORMATION AVAILABLE ON DOUGLAS-FIR PROPERTIES

New information on utilization of Douglas-fir was made available in 1952. The final report is yet to be made on the study of properties of California Douglas-fir, started by the Forest Products Laboratory in 1951, but preliminary analysis shows that material from the Coast Range west of Redding had a specific gravity comparable to Douglas-fir of the "coast type from western Oregon and Washington". Since specific gravity is a criterion of mechanical properties it is expected that Douglas-fir from this area will rank well in strength qualities. Material from the Sierra Nevada area showed somewhat lower specific gravity.

A Forest Products Laboratory study of the veneer cutting and drying properties of Douglas-fir showed that peeler material from the Coast Range 35 miles west of Redding, behaved much like old-growth Douglas-fir from the Pacific Northwest. The logs studied ranged from 27 1/2 to 40 inches

in diameter and had ring counts of from 190 to 265. Peeler logs from the area would logically go to plywood plants in the Sacramento Valley. Some Douglas-fir plywood is now being produced in this area and this additional information may help to produce a better quality product.

Increased production of Douglas-fir lumber has stimulated some standardization of lumber grading rules. Until recent years the rules of the West Coast Bureau of Lumber Grades and Inspection were not commonly used in the pine region of California. Now some mills ship Douglas-fir and white fir lumber under both Western Pine Association and West Coast rules. Steps have been taken by the two associations to bring certain of the comparable grades in both rules into closer conformity. If the West Coast rules become more widely used, further steps toward standardization of grades may logically be expected.

WOOD PROPERTIES STUDIED IN CALIFORNIA HARDWOODS

We have continued to add technical information on the properties and behavior of local hardwoods. Data are now available on air drying methods and dry kiln schedules for some of these woods. Veneer cutting and drying characteristics have been studied. Machining qualities have been studied, and, through the assistance of the Forest Utilization Service unit at the Northeastern Forest Experiment Station, preliminary trials were made of the behavior of these woods in turning lathes and dowel machines. Madrone and California laurel showed up well in these trials. Trial runs on a somewhat larger scale may be made a little later on.

Plywood manufacturers in the redwood region who operate slicers are carrying on experimental work in slicing hardwoods. The combination of sliced hardwood face veneers on softwood cores should add materially to the value of product from these plywood plants. The West Coast market, which now looks to the eastern United States and foreign countries for its hardwood veneers, should provide a ready outlet for local hardwood veneers.

Further interest in the local hardwoods has been shown by eastern firms as well as by government agencies which use hardwood lumber on the West Coast.

FOUR LOCAL HARDWOODS IN SEASONING TESTS

Two experiments are in progress to learn more about the seasoning of four California hardwoods: chinquapin, California laurel, madrone and tanoak. One experiment, including test material of all four species, was started in the

spring of 1951 and is complete except for the final report. The results indicate that of the four species, laurel can probably be dried with no particular difficulties. Tanoak can be dried using the same care as in drying some of the more refractory eastern hardwoods, such as the bottom-land oaks. Madrone does not check seriously, but shrinks and warps considerably in drying. Considerable care will have to be exercised in piling this wood for drying. It will dry best in relatively thin, narrow pieces, using piling stickers on 12-inch or 18-inch centers. Chinquapin appears to be the most difficult of these woods to dry.

We had expected to complete the second experiment, including only tanoak and madrone, before the end of 1952, but have awaited the use of a small experimental kiln being built at the cooperating plant that will enable us to get more information on the kiln drying of these two woods. Two thicknesses were sawed, 7/8" thick and 5/4" thick. The thinner stock has already been kiln dried along with redwood in a commercial kiln using drying conditions estimated to be satisfactory for the hardwoods. The results indicate that the thinner sizes of these two species can be kiln dried with little difficulty after first being air dried to a moisture content of 20 percent or less.

BETTER UTILIZATION SOUGHT THROUGH LUMBER SEASONING

The possibilities for improving utilization of forest products through better lumber seasoning appear to be great, and we have spent considerable effort working with the industry in this field. Maintaining lumber grades during drying and increasing the capacity of dry kilns and air-drying yards through better operation, were the most frequent topics of discussion. Much of this work was done through the Station's participation in meetings of dry kiln clubs and lumber seasoning associations. Our aim in consulting with manufacturers and operators was to discuss wood properties and seasoning principles that can help manufacturers produce the best equipment possible, or operators use their equipment to best advantage. We have avoided assisting individuals design and build their own equipment, for we feel that this is the field of manufacturers and consulting engineers. Seldom do home-made kilns perform as well as those built by experienced kiln companies or engineers.

The Forest Utilization Service has also followed the special drying processes that have been tried in the area. One of these appears to be worth further study. It is a method of drying lumber in a closed chamber under controlled humidity conditions at atmospheric temperatures. Moisture is controlled

by a humidifier and condenser unit. Only enough heat is supplied to maintain atmospheric temperature within the closed chamber. This is in contrast to the conventional method in which high temperatures are used and humidity is controlled by venting air in the kiln to the atmosphere.

AGRICULTURE INCREASES USE OF SAWDUST AND SHAVINGS

The use of sawdust, shavings, bark chips, and similar wood waste is increasing. Much of this material is now being used in agriculture. The use however, is the result of favorable circumstances and deliberate effort by the producer to merchandise the waste.

One sawmill located favorably in the agricultural region at the south end of the San Joaquin Valley is now disposing of all sawmill sawdust and bark from a rotary-head log barker to stockmen for bedding material. Dry sawdust and shavings from the remanufacturing facilities at the same mill are used for higher value products. The baled, dry shavings are used for poultry litter. Since the demand is seasonal at this mill, and for relatively short periods in the summer the supply is in excess, the operator now plans to incorporate sewage sludge with the sawmill sawdust and bark to produce an acceptable soil amendment, to be used either directly or after composting.

At least one sawdust processor in Los Angeles is unable to obtain a sufficient supply of dry sawdust and shavings to meet the growing demand. We assisted by suggesting additional sources and supplying information on sawdust dryers.

BETTER CHARCOAL KILN NEEDED FOR WOOD WASTE

We receive many requests for information on how best to utilize mill left-overs such as slabs and edgings, also timber cleared from land being put to other uses. There is now a limited market for bark-free slabs and edgings in making wood pulp and fiber. A considerable volume of trim-ends from box factories and lumber remanufacturing plants is also similarly used. These uses are relatively limited, however, and other methods of utilization are needed. The manufacture of charcoal or the compressing of wood fibers into briquets for fuel may be at least partial solutions. A San Francisco manufacturer of pelletizing equipment is now operating a pilot-plant installation producing fuel pellets at a box factory in the San Joaquin Valley. Results of this first installation may lead to much wider application.

At least one new battery of charcoal kilns is now in operation on round and split wood. These kilns, though made

of reinforced concrete and of a modern design, require almost continuous attention when in operation and are loaded and unloaded by hand. We feel there is great need for a new type of charcoal kiln that can be loaded and unloaded mechanically and operated automatically. To be completely suitable it would have to be either extremely cheap or portable.

WOOD STRUCTURES STUDIED FOR EARTHQUAKE RESISTANCE

Plans were made during the year for a study of particular interest to the structural engineers of California. This is a project to determine the resistance of wood walls and diaphragms to earthquake forces. The work will be done by the Forest Products Laboratory in cooperation with the State of California and the U. S. Corps of Engineers. Since wood construction holds an important position in the construction field, it is essential that the best possible information be had for safe design purposes. The project is of special interest in connection with the large state school building program in which wood construction is used extensively.

RANGE RESEARCH

Knowledge that will contribute to maximum sustained production on California range lands was developed in four fields of study during 1952. In the field of brushland improvement, results of experimental work emphasized the importance of improving selected areas and of continuing effort to maintain forage plants established after removal of brush. Foothill range management studies returned additional evidence of benefits from such cultural practices as range fertilization. Reseeding studies made progress in testing grasses and legumes for northeastern California, showed ways to improve reseeding sites, and confirmed the value of chemical sprays for control of competing vegetation. Studies of mountain range management were broadened by a new cooperative project on restoration of browse species.

FORAGE PRODUCTIVITY STUDIED IN NEW BRUSHLAND TESTS

New experimental areas were established in the brushland improvement project for the purpose of evaluating the productivity of the sites for forage as well as testing different methods of brush removal and reseeding. These new plots were located in the Mendocino and Tahoe National Forests in cooperation with administrative personnel. We are working, also, with the California Department of Fish and Game on the Mendocino National Forest and with our

Division of Forest Management Research on the Tahoe National Forest. Soils on the plots were classified by personnel of the Forest Economics Division working on the vegetation-soil survey. On older experimental areas we have classified the soils under a broad breakdown between "woodland-grass" and "brush" soils. This breakdown is based on the classification used in the cooperative vegetation-soil survey in California. In general, good forage covers have been established on the soils typically associated with woodland-type range, but success has been spotty on the soils typically associated with chamise brush. From the new plots we hope to get information that will help improve the usefulness of the vegetation-soil survey and refine site evaluations for brush conversion.

SMASHING BRUSH PAYS IN CLEARING PROGRAM

Studies of how to remove the brush on selected areas have included fire, mechanical means, or combination methods. Trials during 1952 have supported earlier observations that some investment in smashing brush preparatory to burning will pay good dividends. Effective burns were obtained under moderate fire weather conditions on areas where the brush had been smashed with a bulldozer, at times when fire would not burn in standing dense brush. Smashed brush could be burned in the evening and at other times when danger from spot fires in light fuel was at a minimum. The results show that smashing brush before burning makes possible a more orderly, planned program of brush removal on selected areas.

Range Research participated with the Division of Fire Research in trials aimed at defining the conditions of weather and vegetation that permit effective use of area ignition. In brush removal, area ignition is a combination of pre-treatment and rapid firing for most effective combustion under comparatively safe burning weather. Cooperating in the area-ignition trials are the School of Forestry, University of California; California Forest and Range Experiment Station; California Agricultural Extension Service; and the State Division of Forestry. Guides to use of the technique are now being prepared.

A combination of brush-removal methods is being compared with broadcast burning as a means of removing excess woody plants in the open stand of trees and shrubs at the San Joaquin Experimental Range. The most effective means of removing shrubs such as ceanothus appears to be to smash the shrubs with a light tractor and then burn them. Chemical stem treatment appears most promising for killing trees, but the limited tests in 1952 indicate that considerable work is

needed to develop more positive methods for killing liveoak. Digger pine is readily killed by stem treatment with 2,4-D.

Tests of chemical sprays for control of brush sprouts continued to show promise. On a burned chamise-chaparral area, broadcast application of a heavy ester of 2,4-D at 2 pounds acid equivalent per acre appears to have given excellent control of sprouts and seedlings that grew the first year after the fire. In woodland-chaparral types, on the other hand, liveoak and toyon sprouted vigorously in 1952, the second year after treatment, with 2,4,5-T. Repeat treatments appear to be necessary for control. Although these second-year results were disappointing, chemical treatment still shows more promise than other methods tested for controlling such vigorous sprouters as liveoak. Therefore, we are planning additional cooperative work with the University of California to help develop more positive treatments.

RESEEDING AIDS CONTROL OF INVADING BRUSH

Reseeding cleared areas aims to provide a plant cover that reduces the risk of erosion, delays reinvasion of brush, and increases grazing capacity. Differences in the effect of reseeding on brush reinvasion and grazing capacity became more apparent during the year. In burned woodland-chaparral, excellent control of brush seedlings was recorded in a re-examination of plots sown in the fall of 1949 and reburned during 1951. Artificial reseeding had established the continuous grass cover needed for reburn fuel and for a satisfactory kill of brush seedlings. On some unsown plots the grass cover from natural growth of resident annual grasses was sufficient to carry a fire that killed all the brush seedlings; on other unsown plots the reburn killed only a few brush seedlings. The conclusion from the studies is that artificial reseeding is needed in burned woodland-chaparral to assure the necessary continuous herbaceous cover over the entire area. But reseeding and reburning have not controlled sprouts of liveoak and certain other species in woodland-chaparral. Follow-up chemical control is needed and should be standard practice on reseeded land as soon as positive methods of chemical treatment have been developed.

Artificial reseeding in woodland-chaparral has resulted in increased forage yields during the first two years and has established superior forage species. Once established, annual legumes have increased in number each year, but the widespread problem of getting legumes established is far from solved. Also, sound fertilization and management practices must be developed for different conditions so that maximum returns can be obtained from reseeding on cleared woodland-chaparral.

Reseeding results were generally poor in burned-over chamise. On sites of relatively low productivity, the grass stands three years after sowing were still spotty and furnished insufficient fuel for a reburn. Chamise seedlings and sprouts are recapturing these plots. One exception is worthy of note. On a chamise site with deep, fertile soil in the Sierra Nevada foothills, grass reseeding was successful, and a reburn in 1952 appears to have given good control of chamise seedlings on some plots. The new plots on the Mendocino Forest were installed mainly where we have had difficulty in establishing good grass stands, to learn more about the forage species that may be adapted to these sites and to develop better reseeding methods.

In these tests the seed was covered with a new flexible roller designed by project personnel, especially for use on hard, uneven seedbeds with rocks or numerous dead brush stems. The experimental roller offers real promise, and these tests will be expanded in 1953. Another device developed on the project is a simple pyrometer useful in recording seedbed soil temperatures which occur during burning. This pyrometer makes possible many more records than can be obtained with expensive thermometer or thermocouple installations.

SINGLE FERTILIZATION BOOSTS FORAGE FOR THREE YEARS

Research on foothill range management at the San Joaquin Experimental Range included measurement of growth and production of forage, utilization of the forage by cattle, and wildlife relationships. As in the past, these studies were conducted in cooperation with the Division of Animal Husbandry and Zoology, University of California. During recent years, the chief aim of our work has been to evaluate fertilization as a means of improving the annual-plant forage. Good returns from sulfur fertilization were obtained in 1952 on small plots fertilized in January 1949. This is the third productive year from a single fertilizer application; no increased yields were obtained in 1949, which had a dry spring season. The greatest total increase in yield during the three-year period was from single superphosphate applied at 600 pounds per acre. Gypsum at 350 pounds per acre and soil sulfur at 60 pounds per acre each produced smaller increases in yield, but more economical returns.

Considering the estimated cost of fertilizers and spreading, the increased production of dry herbage over the three-year period cost $2.51 per ton on gypsum plots, $2.95 per ton on sulfur plots, and $5.49 per ton on superphosphate plots. Fertilizing with either sulfur or gypsum at three-year intervals and at the rate of 60 pounds sulfur per acre,

total cost approximates $1.00 per acre per year.

Similar results were obtained on a 40-acre area fertilized in January 1949 with a mixture of sulfur and superphosphate. In 1952 the total yield of dry herbage in the fertilized area was 4,095 pounds per acre compared with 2,562 pounds in a control area. Total yield was 1,533 pounds greater, yield of grasses was 1,150 pounds greater, and yield of legumes was 380 pounds greater. Miscellaneous species produced slightly greater yields in the fertilized area, while filaree yielded slightly less. Since 1949 the fertilized area returned a total increase in grasses of 2,725 pounds; in legumes 1,418 pounds; and in miscellaneous plants, 129 pounds. Yield of filaree was reduced 646 pounds. Because stimulation of clovers in the fertilized area was less during 1952 than in the two previous years, gypsum will be spread to raise the level of sulfur in the soil, in an attempt to stimulate legume growth in 1953.

Range fertilization on a larger scale is being tested on a 1200-acre area at the San Joaquin Experimental Range, grazed by one of the breeding-cow herds. An excellent growth of legumes was obtained during 1952 on 280 acres of this area, fertilized with bulk gypsum in October 1951. Soil sulfur was applied with an airplane on an additional 400 acres in May 1952; first herbage response on this area is expected in 1953. The remaining 520 acres will be fertilized in 1953.

One objective of the studies on fertilized range areas is to determine the extent to which seasonal deficiencies in quality or quantity of the natural forage can be overcome by range fertilization. The results are being measured in terms of livestock production as well as forage yields and composition. In this test two small fertilized areas and their controls are stocked with two groups of weaner steers. Additional animals are added to the fertilized areas in an attempt to obtain equal forage utilization between fertilized and unfertilized areas. Supplements are fed to each group of steers as needed to maintain a normal growth rate. The effects of fertilization are measured in terms of cattle gains and needs for supplemental feeds. Results from the tests are still preliminary; steers have been carried through the entire year on fertilized forage for only one year.

Competition between rodents and cattle for use of the foothill forage crop is being studied in two areas grazed by weaner heifers during the green forage season. The two areas were grazed in 1949 and 1950 with a natural population of rodents in both; in 1951 and 1952 with ground squirrels

removed from one area. Reversal of treatment in 1953, a planned part of the experiment, is needed before conclusions can be drawn.

GRASSES, LEGUMES TESTED IN NORTHEASTERN CALIFORNIA

In northeastern California, where most of our range reseeding experiments were carried out in 1952, three grasses proved adaptable to poorly drained sites. These range sites are submerged for three to eight weeks each spring when snow melts. Then in late summer the heavy clay soil dries out and cracks badly. The range is dominated by silver sagebrush and ordinarily produces little forage. On reseeded plots tall wheatgrass and meadow foxtail are the two grasses that have given the highest production of forage on this type of range. Smooth bromegrass has also been successfully grown here. Intermediate wheatgrass has not proved to be adapted to poorly drained areas; many well-developed plants drowned out the second year after establishment.

Several grasses have proved adapted for reseeding other sites in both the Great Basin sagebrush and ponderosa pine zones, as we reported in 1951. Success with legumes, however, has been very limited. Cicer milk-vetch has given the most consistent establishment on the better-drained sagebrush range sites. Fairly good emergence has been obtained from fall as well as spring seeding. A mat-forming root system and vegetative spread aid its survival under attack by rodents. Dry-land alfalfa appears adapted to the soil and moisture conditions, but depredations by rodents and other wild animals limits its use. Also, spring seeding seems necessary for alfalfa to become established on grazing areas at elevations of 5,000 feet or more, but this season of planting is usually unsatisfactory for grasses. All in all, it will be difficult to obtain a desirable mixture of grasses and legumes. More testing will be needed to find more suitable legumes and techniques for establishing them before widespread seeding can be recommended.

WAYS FOUND TO IMPROVE YIELD ON SAGEBRUSH RANGES

Ridging the soil seems to be one way of improving site conditions on poorly drained range subject to spring flooding. Grasses seeded on ridged plots have produced from 22 to 70 percent more forage than those on flat plots. The low ridges were prepared by back-furrowing at 12- to 18-foot intervals across the field. This method of plowing would add very little additional expense to site preparation for reseeding because some type of plowing is required to rid the area of silver sagebrush competition ahead of seeding. Improvement of drainage is the key to improvement of this

unproductive range type. Ridging offers promise as the most practical method for providing better drainage.

Range improvement through fertilization also looks promising in northeastern California. Grass production was greatly increased on plots fertilized with ammonium nitrate at the rate of 60 pounds of nitrogen per acre. Effects of one application have been found to carry over for at least three years. Plots fertilized in 1950, 1951, and 1952 produced from 69 to 103 percent more grass in 1952 than unfertilized plots. On this basis, a reseeded range area that is fertilized will produce 5 to 6 units of forage while a similar but unfertilized range will produce only 3 units during a three-year period. The use of 30 pounds of nitrogen per acre has been insufficient for optimum results and 120 pounds per acre has been but little better than 60 pounds.

In another site productivity test, rabbits were shown to cause considerable loss of forage when they are abundant, as they have been recently in the Great Basin sagebrush zone. In this test both rabbits and livestock were fenced out of plots seeded to crested and intermediate wheatgrass in 1948, on the Modoc National Forest. After 14 months of protection, forage production in 1952 averaged 516 pounds per acre. Where livestock were excluded but rabbits grazed, the yield was 198 pounds.

AIRPLANE SPRAYING SUCCEEDS IN RANGE HERBICIDE TESTS

Spraying herbicides by airplane proved feasible for large-scale projects to control sagebrush competing with range grasses. This was shown by 1952 measurements on three areas sprayed in 1951, in cooperation with the Bureau of Land Management and two national forests. The airplane spraying was done with a standard formula using 2 pounds of the butyl ester of 2,4-D per acre in an emulsion of 9 1/2 gallons of water and 1/2 gallon of diesel oil.

On the Bureau of Land Management area, 92 percent of the sagebrush was dead in 1952; many of these plants were 6 to 8 feet tall, much larger than any sprayed on national forest land. Elevation of this area was approximately 5,800 feet. On the Lassen National Forest at 5,600 feet, 89 percent of the sagebrush was killed on a 1700-acre portion of the Harvey Valley allotment. Big sagebrush occupied 20 percent of the area, black sagebrush 64 percent, and silver sagebrush 16 percent. Susceptibility of the three species was not significantly different. Some strips between the airplane swaths were inadequately covered with spray, but where adequate coverage was obtained , 98 percent of the sagebrush was killed.

The highest percentage kill, 99 percent, was obtained on an area sprayed in the South Warner Mountains of the Modoc National Forest, at an elevation of about 7,500 feet. Two species, big and silver sagebrush, were equally represented at this location.

In a test of several herbicide formulations, first results with butoxyethanol ester of 2,4-D were encouraging. Sprayed at the rate of 1 pound acid equivalent per acre, butoxyethanol ester resulted in 97 percent kill of sagebrush. If such favorable results continue through tests now in progress, it may be possible to change from the generally recommended use of 2 pounds of butyl ester per acre to 1 pound of the butoxyethanol ester.

Ground equipment is still needed, however, to spray areas that are small, isolated, or located where trees or steep slopes make flying hazardous. This equipment needs to be sturdy and maneuverable because range land is often rough and rocky. Three types of ground sprayers were tested in 1952. A tractor-mounted boom gave the best spray distribution but was limited in width of swath and in maneuverability. A broadjet sprayer overcame these limitations, but failed to give satisfactory distribution of the spray solution; drops were entirely too large and too widely spaced. A turbine sprayer gave good spray distribution over a 60-foot swath and proved sufficiently maneuverable wherever a 4-wheel-drive power wagon can be driven.

NEW SYSTEM APPLIED FOR MOUNTAIN GRAZING

Pilot-plant testing of a grazing management system based on mountain range research was started during 1952. This system, described in our 1951 report, provides for resting and grazing different units of the range in a systematic way so as to encourage range restoration, maximum forage production, and efficient range use. During 1952, the first of the five pastures involved in this grazing system was operated according to plan. Rested from grazing during the entire 1952 season, this unit will continue to be rested until mid-season 1953. Then grazing will be started again. An excellent stand of grass was obtained by artificial reseeding in 1951 on 300 acres of this unit, and approximately 89 percent of the sagebrush on 1700 acres was killed with 2,4-D spray. Additional pasture units will be geared to the over-all management plan in 1953. Experimental plots will be established to measure the changes that take place as a result of grazing management and the cultural work.

BROWSE RESTORATION STUDY STARTED ON GAME RANGES

A new research project aimed at restoration of browse plants on game ranges was started at mid-year in cooperation with the California Department of Fish and Game. This project is set up for State-wide study. The first work, however, will be directed at deer winter-range problems east of the Sierra Nevada crest. Prime consideration will be given to re-establishment of bitterbrush, the most important winter deer feed in this region.

Much that is needed in a successful reseeding formula is unknown. For example, little is known of how intensive a land clearing job--aimed at reduction of plant competition--is needed on various sites for acceptable seedling germination and survival, or of how this clearing can be done practically on extensive acreages of rough terrain. Just how and when to plant are largely unsolved questions. And little is known of the effect of rodents, birds, and insects on the planted seeds and seedlings, and of ways and means to minimize such damage.

During the time available in the fall of 1952, range conditions and site differences were reconnoitered in the winter range area extending from the Oregon border to the southern tip of the Sierra Nevada mountains, a stretch of about 400 miles. Experimental plots were established on widely different sites in four locations in this region, from Perez in Modoc County to Bishop in Inyo County. A series of plantings were made at each location with the following three species: bitterbrush (Purshia tridentata), big sagebrush (Artemisia tridentata), and wedgeleaf ceanothus (Ceanothus cuneatus). In one location additional plots were sown with bitterbrush and crested wheatgrass, and other browse species were started in nursery plantings. These included:

Greenleaf manzanita	Arctostaphylos patula
Deerbrush	Ceanothus integerrimus
Birchleaf mahogany	Cercocarpus betuloides
Mountain mahogany	Cercocarpus ledifolius
Bear brush	Garrya fremontii
Sierra juniper	Juniperus occidentalis
White sweet clover - herb	Melilotus alba
Western chokeberry	Prunus demissa
Elderberry	Sambucus glauca

These exploratory plantings were aimed to provide initial information on species adaptability to site, seed germination, seedling survival under different degrees of competition, seed dormancy and germination, time and depth of planting, and the influence of wildlife on seeds and seedlings. During the

winter months of 1953 seed will be tested for germination and herbicides selected for use in eliminating or reducing unwanted vegetation on planting sites. Future field work will be moulded largely on the basis of the reactions obtained in this preliminary work.

FOREST INFLUENCES RESEARCH

Watershed-management research by the forest influences staff continued to place emphasis upon problems in southern California and in the brushy foothill areas of the State. In the south, research was expanded by starting a field plot study to compare the disposition of rainfall under covers of native chaparral, grass, and Coulter pines; soil movement studies in the Los Angeles River watershed were carried into a new stage; and research in plant physiology and ecology, related to soil stabilization work in this watershed, progressed in laboratory and field. A State-wide study of the erosion consequences of fire in brushy foothill areas, started in 1950, was brought to the analysis stage. Investigations in other parts of the State included study of watershed reactions to fire in the foothills of Kings River drainage, and study of erosion control measures in logging areas and on smelter-denuded land.

As in the past, several agencies helped support the research program. The California Department of Natural Resources, through its Division of Forestry, cooperated in the work on the San Dimas Experimental Forest in southern California. Soil and plant studies in the Los Angeles River watershed were carried on in cooperation with the Forest Service Flood Control project and the California Institute of Technology. Officers of the Sierra National Forest assisted in the collection of records for the watershed study in the Kings River drainage.

WAY FOUND TO IMPROVE RAINFALL MEASUREMENTS

Results of a series of experiments designed to improve the accuracy of rainfall measurement in the mountains were summarized during the year for publication. These experiments showed the sources of errors in rainfall measurement, and led to design of an improved type of rain gage placement, in which gages were tilted normal to the slope to be sampled. Tilting the gages gave rainfall catches very close to those of a control surface on the ground, while the conventional vertical gages often caught considerably less rain. But vertical rain gages do not always give low

precipitation measurements; they may give too high estimates where orientation of mountain ranges or prevailing winds are different from conditions at San Dimas. In either case, tilting the gages gives accurate measurements of rainfall in mountainous land.

WATER-LOSS STUDIES EXTENDED TO GRASS

Equipment was designed on the San Dimas Experimental Forest to provide information on the amount of precipitation caught by grass and evaporated before reaching the ground. Very little information exists concerning this kind of interception loss. Metal rings, 6 1/2 inches in diameter and 6 inches high, are set vertically in the soil in such a way that the top edge of the ring, cut parallel to the ground slope, is about 2 1/2 inches above the soil surface. The soil surface is sealed against water penetration, and a drain is provided so that water penetrating the grass cover can be collected. The difference between rainfall and the water collected is the quantity caught by and evaporated from the grass cover. A satisfactory soil sealer proved to be a mixture containing 95 parts of polyvinyl acetate emulsion and 5 parts of tricresyl phosphate plasticizer. The sealer is applied to the soil in a fine, concentrated spray so as to avoid coating the aerial parts of the vegetation.

In order to provide additional information on evapotranspiration processes, two of the lysimeters at San Dimas Experimental Forest recently were planted to perennial grasses and two others to sugarbush (Rhus ovata). These plants are still too small to yield information comparable to that from lysimeters growing five other species--buckwheat, chamise, ceanothus, scrub-oak, and Coulter pine, all 6 years old.

As a result of this year's high rainfall, surface runoff on the lysimeters was 4 times as great as it had been during the preceding years of small, light storms. Seepage through the 6-foot soil blocks occurred for the first time since the study species were planted. In spite of the fact that seepage occurred this year, the quantity of moisture stored in the soil at the end of the dry season was almost identical with that at the end of each of the 4 previous dry seasons, except in the lysimeters supporting oak and pine. In all except these two, soil water content was reduced to wilting point storage in this and the other years. This year's results show that all the plants except oak and pine can remove all available water from the soil during the dry part of a single year. The oak and pine either draw water from the soil more slowly than the other plants, or are not able to dry it as completely.

WATER YIELD, EROSION STUDIES EXTENDED TO NEW STAGE

Early in 1952 we began a new comparison on runoff-and-erosion plots at San Dimas Experimental Forest, of rainfall disposition under three kinds of vegetation. Over the preceding 16 years the influence of a natural oak-chaparral cover on surface runoff, erosion, and evaporative water losses (for 3 years only) had been studied on three sets of triplicate 1/40-acre plots. Virtually no surface runoff or erosion occurred on the plots during this pre-treatment period. In 1952 the brush cover was removed from two sets of the plots, and annual rye-grass (Lolium multiflorum) was sowed upon them. The objective of this stage of the study is to compare rainfall disposition under a grass cover with that under brush. This study seeks an answer to the plaguing question of which cover provides the better control over surface runoff, erosion, and evaporative water losses. In addition a similar rainfall disposition study was established in a nearby plantation of Coulter pine, so that this cover could be included in the comparison. All factors of rainfall disposition are to be measured in the brush, grass, and pine plots.

To follow moisture changes within the soil mantle electrical soil-moisture units were installed in the soil of the study plots. These compact devices were developed on the San Dimas Experimental Forest to permit direct measurement of soil moisture with a minimum of soil disturbance. Three stacks of the moisture units were installed along the center line of each cover type. The moisture units are spaced to indicate soil moisture at intervals throughout the entire depth of the soil, which ranges from 7 to 17 feet.

Sprouting stumps and large perennial herbs on the grass plots were sprayed repeatedly with 2,4,5-T during the past summer. More than half of the stumps and almost all of the large perennials were killed by this treatment. Litter left on the ground when the brush was cut and removed hindered the development of a complete grass cover. Consequently, all the litter possible was removed manually from the plots in the fall and the plot surfaces were burned. The plots were then resown to annual ryegrass, using enough seed to insure a dense stand.

Research on soil-movement processes, centered in the Los Angeles River watershed, also moved into a second stage--that in which the rates and volumes of soil movement on mountain slopes are to be measured. For the first stage of the study, completed in 1951, source areas of sediment had been delineated and soil-movement processes described. Methods of measuring the rate and quantity of soil movement are now being developed, and several types of barriers and sediment

traps have been installed on slopes to test their usefulness for these kinds of measurement. Also, typical paths of soil movement on slopes were studied to learn the size and number of study areas required in various parts of the watershed. The first stage of this study was completed in a few months, but completion of the second stage will require several years.

GROWTH OF PLANTS STUDIED FOR COVER IMPROVEMENT

Research on methods of improving watershed conditions also was centered in the Los Angeles River watershed, where we are trying to discover ways of decreasing the rate of soil movement on steep slopes through manipulation of plant cover. In one phase of the project, greenhouse studies have shown that low nitrogen content of the watershed soils is an important factor in limiting the growth of native plants. These studies were brought to a close in 1952 with the harvest of the last two species to be studied. A field test, now being made to see whether nitrogen fertilization will increase the density of the native chaparral, showed for the second consecutive year that native shrubs in the field grew more vigorously where nitrogen was added to the soil.

A search for non-native plants to use on these mountains was completed, and a screening process was started for promising species. These species may be used to replace or interplant the native cover as a means of increasing the stability of soil on watershed slopes. Seeds of promising species that are not noxious weeds have been requested from many parts of this and other countries. The response to requests has been very gratifying; seed has been received from Arizona, Chile, Canary Islands, Israel, Morocco, Turkey, and Iran. Seeds of 35 non-native species were tested for germination in the controlled-temperature greenhouse at the California Institute of Technology, under combinations of temperature and day length conditions that simulate those in the local mountains. Because plants introduced into the mountain lands must be able to grow on relatively infertile soils, the seeds are planted in local mountain soils as part of the screening process. Those species that grow well will be planted in the field where further study will be made of their suitability for soil stabilization.

Other studies are showing the temperature limits for growth of established plants. Certain native species, either in the field or in the greenhouse, grow well under a wide range of temperature conditions, while others grow well only when temperatures are high. For instance, Ceanothus crassifolius is capable of growing almost equally well under cool and warm conditions, whereas Rhus ovata and R. laurina grow

only under temperature conditions representative of late spring and early summer. Temperature requirements of growth of 10 non-native species were found to fall within the extremes indicated by the Ceanothus and Rhus species. Two of these, Dodonaea viscosa var. augustifolia and Forestiera neomexicana, did not grow under low temperatures. Seven grew well over a wide range of temperatures; these included Cystisus canariensis, Ehrharta calycina, Phalaris tuberosa var. stenoptera, Baccharis pilularis spp. typica, Bromus stamineus, Lolium multiflorum, and Brassica nigra. One species, Lotus berthelotti, grew best at temperatures corresponding to late winter in this area.

The average season of shoot growth for 13 native shrubs was determined for a typical 3- to 4-year period from data collected on the San Dimas Experimental Forest. Season of growth was found to vary with altitude and between species. Adenostoma fasciculatum at altitudes of 1700 to 2000 feet started growing in February and stopped in April; at 3400 feet its growth season extended from March to May; and at 5100 feet its growth began in April and ended in June. The same delay in growth in response to increasing altitude was noted in other shrubs, but growth of different species did not always start at the same time at the same altitude. Thus Artemisia californica and Salvia mellifera started growth at the same time as chamise, but Arctostaphylos glandulosa, A. glauca, Ceanothus crassifolius, C. leucodermis, Garrya veatchii, and Salvia apiana started 2 to 4 weeks later. Photinia arbutifolia, Quercus dumosa, and Rhus laurina started growth early in April at the low altitudes. Rhus ovata started growth 2 weeks later than any of the other shrubs. This information is useful not only in screening species for test plantings, but also in determining the best time to apply chemical sprays for control of vegetation.

SURVEY ANALYZES EROSION ON BURNED BRUSHLAND

Work on the State-wide survey to determine the conditions under which brush burning on watershed land is or is not followed by increased erosion was confined to analysis of the data from 98 localities that were examined in 75 burned areas during the winter of 1950-51. The analysis showed that erosion was active in 92 percent of the areas examined. Acceleration of erosion, determined by comparing the erosion evidence in adjacent burned and unburned areas, was found in 90 percent of the areas examined. A relation was found between erosion and pre-fire plant cover; erosion was greatest in chamise burns, intermediate in burns that had a pre-fire cover of other shrubs and dense woodland, and least in burns that had been covered with dense grass. With few exceptions, erosion increased progressively with steepness of slope.

One product of this survey was prepared for publication. This is a paper entitled "Indicators of Erosion on Watershed Land in California." It explains how to recognize erosion on wildlands and how to determine whether erosion is more rapid than normal. Presented at the February meeting of the American Geophysical Union, at Pasadena, the paper distinguishes accelerated erosion from geologic erosion and suggests the use of qualitative criteria in disturbed and undisturbed areas as a means of determining whether or not erosion is accelerated. It describes indicators of erosion on mountain slopes and in stream channels, together with some indicators of soil stability. The indicators were used in the survey and they should be useful in other field work concerned with erosion.

WATERSHEDS SHOW CONTRAST IN AFTERMATH OF FIRE

Preliminary analysis of records at our Kings River field branch indicated that wildfire had little effect on streamflow and erosion from the Big Creek watersheds this year. A fire in July 1951 had burned the typical foothill woodland-grass vegetation. A good stand of grass grew to cover the watersheds during the current year. The burn had not been severe enough over most of the area to destroy the litter and the seed stored in the soil. Some oak and pine trees and shrubs were killed where there had been heavy accumulations of fuel and hence more intense ground fire than occurred in the grass cover.

The analysis included two of the watersheds, numbers 4 and 6. Streamflow for 1951-52 was compared with data obtained in 1936-37, when rainfall was not greatly different. The streamflow yield of watershed 4 was 23 percent of the annual rainfall in 1936-37, and 19 percent in 1951-52. The yield of watershed 6 was 32 percent in 1936-37, and 29 percent in 1951-52. The small differences in percent of rainfall yielded indicate that this year the watersheds behaved very much as they had in 1936-37, as to annual streamflow. The flow from watershed 4 persisted through the summer and into the fall of both 1937 and 1952, with a flow of .010 cfs on September 30 of the earlier year as compared to .004 this year. In number 6 all flow stopped on June 12, 1937, and on June 10, 1952. Very little erosion occurred during the 1951-52 rain season. Occasional sloughing was observed along some trails. There was no soil movement into stream channels, and no gouging of stream channels or undercutting of stream banks.

On the other hand, evidence that peak flows and erosion had been increased by wildfires was seen in two chaparral burns of 1951. One was the Cherry Canyon burn in Los Angeles County, examined in February 1952. Bedrock was freshly

exposed in areas 25 to 50 feet across on some slopes, and there were large deposits of sand in the upper drainage channels. The nature of the deposits indicated that wind was the principal agent of erosion, but the slopes and wind-laid deposits were also gullied by runoff that had moved large quantities of sand downstream. The study included examination of small burned and unburned watersheds that lay side by side and were alike in size, topography, soil, and pre-fire cover. This examination showed that peak flows had been low and that there had been practically no erosion in the unburned areas, while both peak flows and erosion had been high in the burned areas.

The other chaparral burn was the Navajo-Black, in San Luis Obispo County. In January 1952, the burned slopes were ribbed with shoestring gullies, and stream channels in and below the burn were filled with sand which had been deposited since the fire. More than a mile below the burn, runoff from the burned area had cut a gully about 5 feet deep across a cultivated field, and the roadside ditches had been filled with sand and debris from the burn. Sediment from the burned area was in transit downstream to Salinas reservoir. Examination of unburned slopes showed no evidence of runoff or soil movement.

EROSION CONTROL METHODS STUDIED ON LOGGING AREAS

Work was started to develop specifications for measures that will prevent or reduce soil erosion and other watershed damages incident to logging. This project is a joint undertaking of the Station and the Regional Office of the U. S. Forest Service. During the 1952 field season a 3-man team of Station and Regional Office workers examined logging areas on six national forests in California. Their objective was to determine the kinds and causes of watershed damage associated with logging, and to appraise current preventive and control efforts.

Wide differences in degree of damage were found in different areas, sometimes resulting from inherent differences in erosibility of the soils, but more often from differences in the amount of precautionary planning of the logging operation, and in the amount of preventive drainage and soil stabilization work done during or immediately after logging. The study group is now preparing a handbook to guide forest officers in reducing watershed damages due to logging. The handbook will depict good and bad practices, and recommend measures for preventing or minimizing excessive soil erosion, stream clogging, and water pollution.

PLANTED PINES CONTROL GULLIES ON DENUDED SLOPES

Examination of experimental plantations of pine trees showed they have controlled erosion where they have become established in the smelter-denuded area above Shasta reservoir. The trees were planted in 1936 on heavily gullied slopes. Three years ago small dams of cut brush were built to plug large gullies in planted and unplanted areas. This year we compared the amounts of eroded soil caught by the brush dams. Those within the plantations showed no deposition, and gullies 2 to 5 feet deep appeared fully stabilized under a matted litter of pine needles. In adjacent unplanted areas where the growth of native manzanita shrubs was insufficient to form a cover, many brush dams were filled with eroded soil, and the bare gully sides were subject to erosion.

The trees that wrought the change on this severely eroded land are Jeffrey, ponderosa, and sugar pines that were set out as two-year-old plants. Planted 3 to 5 feet apart to give early soil protection, the trees after three years showed survival of 97 percent for Jeffrey pine, 89 percent for ponderosa pine, and 67 percent for sugar pine. In 1952 the loss for all three species since 1939 was estimated at less than 10 percent.

Approximately half of this eroded area, denuded in 1906-1912, has been gradually reclothed with a fair cover of native shrubs and trees, but some 32,000 acres are still very bare, and are actively eroding into the Shasta and Keswick reservoirs. For these "bad lands" the experimental plantations have demonstrated that control of the soil through planting is possible.

FLOOD CONTROL SURVEYS

Flood control survey work by the Station was largely discontinued in August 1952. Survey work under way in Oregon in cooperation with the Pacific Northwest Forest and Range Experiment Station, was terminated July 1, and all records were transferred to the Pacific Northwest Station. We have retained one man at this Station to carry on the necessary work in reviewing reports for California watersheds.

The records transferred to the Pacific Northwest Station constitute the ground work for a comprehensive land management plan for the portion of Oregon west of the Cascade Divide and for the Harney Basin of central Oregon. A general reconnaissance survey was made of this area. Sample areas

were established on 16 small watersheds and were studied intensively. Flood control programs were prepared for these watersheds and costs and benefits calculated. In cooperation with the administrative branch of the Forest Service an inventory of needed improvements was prepared for all national forest land and for all public range land. Various phases of this program were analyzed as to hydrologic effects, flood damage reduction, and costs and benefits. Particular attention was given to a study to determine the feasibility of small, multiple purpose flood-control and water-storage projects recommended by local interests. Besides complete reports on the sample areas, rough draft reports were furnished for the major subdivisions for which this Station had been responsible.

Eight California reports have been submitted for review by the Department of Agriculture, other Federal agencies, and state agencies. Among these are three for which the Soil Conservation Service had primary responsibility: Salinas River, Russian River, and Pajaro River watersheds. The Station assisted with wild land surveys for these three. Survey reports for which the Station had primary responsibility include: Wrightwood on Sheep Creek, tributary to the Mojave River; Santa Maria River watershed; San Gabriel-Santa Ana River watersheds; Santa Clara River, Ventura River, and Calleguas Creek watersheds; and western San Diego County watersheds.

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